THE INFLUENCE OF THE DATE OF SEEDING WHEAT ON THE RELATIONSHIP OF AVAILABLE SOIL NITROGEN TO YIELD AND PROTEIN CONTENT

by

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INTRODUCTION

The yield and quality of wheat are affected by variety, stand and stooling, wind damage, disease damage, supply of available moisture, and the supply of available plant food. An understanding of these factors and their relationships is necessary to the production of a constant supply of high quality wheat with the greatest economy of soil resources and human effort.

The selection of the proper variety for local conditions is a factor of vital importance and one in which great progress is being made. The yield, as will be shown later, is highly correlated with stand. Information on the control of the more important insects affecting wheat is now available. The plant pathologists have studied most wheat diseases and are able to recommend effective control measures.

The wheat plant must have certain nutrients available for the proper development of the wheat kernel. The three elements usually considered in connection with the proper fertilization of the soil are potassium, phosphorus and nitrogen. Experimental results show that Kansas soil contains an abundance of potassium and that the addition of

this element often reduces rather than increases the yield. Wheat responds to the addition of phosphorus to certain soils in Kansas. According to Salmon and Throckmorton (17)* those Kansas soils which need fertilizers usually respond best to phosphorus or to phosphorus and nitrogen. One of the important factors in the production of wheat in eastern Kansas is a sufficient supply of available nitrates in the soil. Call (2) states, "When the yield of wheat is compared with the nitrates in the soil at seeding, it will be seen that they are very closely correlated." Sewell and Swanson (18) point out that the percentage of protein in wheat and the pounds of protein produced per acre are very closely correlated with the amount of nitrates in the soil at seeding time.

Moisture is, no doubt, the most important factor in winter wheat production over most of the hard red winter wheat producing area of the Great Plains region. Manhattan is situated on the eastern edge of the Great Plains area and normally receives sufficient rainfall to produce a wheat crop. Call (2) says in reporting on four years of wheat seed-bed preparation work located on the Agronomy Farm, at Manhattan, "There is very little if any correlation

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* Number in parenthesis refers to literature cited.

between the amount of moisture in the soil at seeding and the yield of wheat secured." However, shortage of moisture at certain critical periods in the development of the wheat plant, notably the time of filling, does reduce the yield.

The presence of Hessian fly is sufficient cause for sowing wheat late enough to escape the fall brood of this insect. The Hessian fly is not a serious factor in yield in some years and when certain varieties are used. However, for other reasons, early-sown wheat usually does not make as high yields as when sown somewhat later. Late-sown wheat rarely makes as high yield as that sown on an intermediate date. The highest yields of wheat at Manhattan are secured by sowing between September 20 and October 5.

The experiments herein reported were undertaken to study the affect of the date of planting wheat on the yield and quality of grain produced, the supply of available nitrates in the soil at various stages of the plant growth, the supply of available moisture, the stand and stooling of the plants, and the correlation of these factors.

REVIEW OF LITERATURE

A large amount of experimental data have been published pertaining to the date of sowing wheat and the relationship

of soil nitrates to wheat yield. Little information, however, has been published in regard to the influence of the date of seeding wheat on the relationship of available soil nitrogen to the yield and protein content.

The yield of wheat differs greatly in every section of the United States when the date of seeding is varied. This variation may be caused by one or more of several such factors as the affect on moisture or food supply, poor root development and therefore increased winterkilling, damage from Hessian fly, lack of stooling and variation in date of maturity.

Leighty and Taylor (9), at Arlington Experiment Farm, found that wheat seeded on October 5 made a higher yield than that seeded either September 15 or October 30 when planted on a seed bed prepared at the time of seeding and when seeded at seven rates varying from two to eight pecks per acre. At Pullman, Washington, Shafer and others (19) seeded wheat from August 1 to December 1. They report, "The wheat sowed medium early gave a higher yield than when seeded very early or very late."

Klages (8) says, "Winter wheat must be sown early enough in the season to give the plants an opportunity to establish themselves thoroughly before the advent of low temperatures with the approach of winter. Yet the seeding

of the crop earlier than is required for this will lead to decreased rather than to increased yields."

The best date of planting wheat at Hays, Kansas, according to Swanson (20) is from September 20 to October 1. This work shows that a higher yield is secured on September 22 and September 29 than on September 8, September 15, or on any date after October 6.

Unpublished data taken from the reports of the Kansas Agricultural Experiment Station crop production project at Manhattan show that the highest average yield is secured when wheat is planted September 21 to 24 at the rate of four pecks per acre, September 28 to October 1 at six pecks, and October 4 to 8 at eight pecks per acre.

This review indicates that wheat can be seeded too early or too late to secure the highest yield and that a medium-early seeding date is the best.

Data are available to show that the earlier the seed bed is prepared, the higher is the yield of wheat. Investigations have shown that this increased yield is due to an increase of soil nitrates or moisture.

Call (2) reporting on various methods of wheat seedbed preparation at Manhattan, Kansas, says that there is a close correlation between the amount of nitrates in the

soil at seeding time and the yield of wheat. The application of nitrate of soda increased the yield of wheat on corn-stalk ground but failed to increase the yield on the seed bed plowed in July which contained a high amount of nitrates.

Data secured from wheat seed-bed preparation plots over a nine-year period as reported by Throckmorton and Duley (21) give a direct correlation between soil nitrates at seeding time and yield. While the percentage of protein in the wheat was not so closely correlated with soil nitrates as was yield, the protein did increase with an increase in soil nitrates.

Kiesselbach and others (7) found that when wheat was grown on seed beds prepared by different methods, the highest yields were secured where the nitrate development and moisture accumulation were greatest from July to October. Those seed-bed treatments which result in high yields also produced grain that was relatively high in protein content.

Under conditions of adequate rainfall, citations indicate that there is a closer correlation between soil nitrates and yield than between soil moisture and yields. However, under conditions of light rainfall the opposite may be true. McCall and Wanser (11) reported methods of summer fallowing for wheat production at the Adams Branch

Experiment Station, at Lind, Washington. The average annual rainfall for the seven-year period was 7.68 inches. They report as follows: "There is a significant positive correlation between soil moisture and accumulated nitrate-nitrogen and yield of straw and grain, indicating that both factors must be given due consideration in preparing the fallow. There is a more significant correlation between grain yield and soil moisture content then between grain yield and nitrate-nitrogen accumulations. Moisture conservation is, therefore, the most important function of the summer fallow under conditions such as prevailed during the experiment herein reported."

Neidig and Snyder (13) secured an increase yield of both Marquis and Palouse Bluestem wheats by the addition of nitrates to soil sand mixtures, in the greenhouse. Palouse Bluestem wheat was grown in cylinders placed in soil plots. Sodium nitrate was added to different cylinders in each plot. They report as follows: "The results of this series showed that when there was a sufficient amount of available nitrogen present in the soil to insure a maximum plant growth during the early period a high yield was obtained. When the nitrogen supply was sufficient to insure an available supply during the entire life cycle of

the plant, both a high yield and a high protein content were obtained under the climatic conditions which existed during this experiment."

Other investigators including Gericke (6), Russel (16), Murphy (12), Davidson and LeClerc (4), and Pendleton (15), report that the yield and protein content of wheat can be influenced by the nutrients which are available for the use of the plant, especially if soil nitrates are present in limited quantities before the nutrient is applied.

MATERIAL AND METHODS

Location and Arrangement of Plots

The experimental work was conducted during the two seasons, 1931-1932 and 1932-1933. The plots were located on the Agronomy Farm, one mile north and three-fourths mile west of the Kansas State College campus, Manhattan, Kansas. The soil consists of a brown mellow silt loam which passes at a depth of about 12 to 15 inches into a lighter brown to reddish, friable silty clay loam, this grading beneath into yellowish-brown less compact silty clay loam including calcareous concretions at a depth of approximately three feet. This soil has been classified as Derby silt loam.

The arrangement of plots as indicated in Fig. 1 was the same in both 1931-1932 and 1932-1933. Each plot was twelve drill rows, or seven feet wide, and consisted of one-forty-seventh of an acre in 1931-1932 and one-fortieth of an acre in 1932-1933. Two adjacent plots were planted on each of seven dates as indicated in Fig. 1. The first plot planted on each date was used for securing soil and plant samples. Yields were secured from the second plot. This method was used to avoid error in yield due to damage from soil and plant sampling.

Seed-bed Preparation and Seeding

A rotation consisting of corn, oats and wheat has been practiced on the fields on which the plots were located. The seed bed was well prepared, having been plowed in July, disked and harrowed sufficiently to produce a good seed bed. Volunteer oats made it necessary to cultivate the 1931 seed bed several times immediately before planting. Plots 5, 6, 7, 8, 9 and 10 were disked on September 29 after plots 1, 2, 3 and 4 were planted. The volunteer oats did not influence the stand to any appreciable extent either season.

Certified Kanred seed wheat grown on the Agronomy

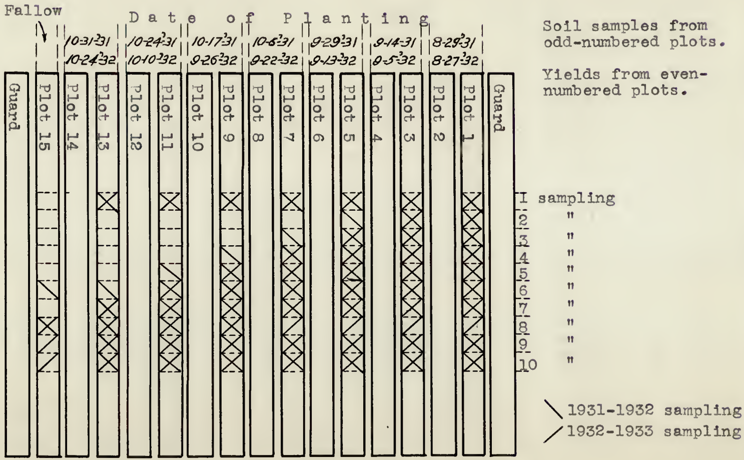

Fig. 1. Outline of plots 1932 and 1933.

Farm in 1931 was seeded in 1931. As will be shown later, the early plantings were badly infested with Hessian fly. In order to eliminate this factor as much as possible, Kawvale, a Hessian fly-resistant variety, was seeded on the 1932-1933 plots. The Kawvale seed was harvested from the 1932 wheat variety plots.

Moisture and Nitrate Determinations

Soil samples for moisture and NO_3 determinations were taken from the top three feet of soil, in sections of one foot, with a regulation soil tube. The samples were immediately placed in tin soil cans which were kept closed to prevent evaporation. Soil samples were taken in all plots on the first planting date; thereafter, the plot to be planted and all previously planted plots were sampled on each planting date as indicated in Fig. 1. Samples were also taken in all plots when the wheat was entering dormancy in the fall, when emerging from dormancy in the spring, and at time of heading of earliest plots. The area sampled on each date was seven by five feet. Three borings, one in the center and two in opposite corners, were taken at each sampling.

Moisture and NO_3 determinations were made the same day the samples were taken when possible. When it was necessary

to hold the samples over night, they were stored in a cool place.

In the laboratory the soil was first run through a one-fourth inch hail screen sieve and then thoroughly mixed on an oilcloth. Fifty-gram, duplicate samples were weighed on a Torsion balance for moisture determinations. The samples were then dried in an electric oven at 110 degrees Centigrade until there was no further loss in weight. The percentage of moisture was determined on a dry basis.

One fifty-gram sample of the screened soil was taken for a nitrate determination. The nitrate content was determined by the phenoldisulphonic acid method as follows: The fifty-gram sample was placed in a battery jar, 250 c.c. of distilled water was added and the mixture thoroughly agitated in a stirring machine for three minutes. It was then allowed to stand ten minutes for settling and the clear liquid filtered into an Erlenmeyer flask. Duplicate 50 c.c. portions of the filtrate were measured into porcelain evaporating dishes and evaporated. The dishes were then allowed to cool and two c.c. of phenoldisulphonic acid were added. The dish was then rotated until the acid came into contact with all residue. After ten minutes, 15 c.c. of distilled water was added and the whole stirred

thoroughly with a glass rod. The dish was allowed to cool and NH_4OH was added slowly until a permanent yellow color developed.

Two 10 c.c. samples of standard KNO_3 solution were evaporated, the color developed and each made up to 100 c.c. The two standards were read against each other on the colorimeter. If they agreed they were considered correct and used as a standard for securing readings on the unknown samples.

The liquid from the evaporating dish of an unknown sample was then transferred to a graduated cylinder and diluted until the color approximated that of the standard. A comparative reading between the known and unknown solution was secured and from these the parts per million of NO_3 in the unknown calculated according to the following formula:

$$\text{p.p.m.} = \frac{(W + Y)\ DK}{(S - Y)\ AU}$$

S = grams of soil taken
Y = grams of water in soil sample
W = c.c. of water added to the soil
A = c.c. of aliquot taken for evaporation
D = c.c. to which A was diluted
U = the reading of the unknown solution
K = the reading of the standard solution

The pounds of NO_3 per acre were calculated by multiplying the p.p.m. in the first foot of soil by 3.6, in the

second foot by 3.8, and in the third foot by 4.0, representing, respectively, 3,600,000, 3,800,000 and 4,000,000 pounds of soil per acre foot.

The wilting coefficient of the first, second and third foot levels was secured by the hydrometer method. Fifty grams of oven-dry soil were mixed with water on the stirring machine for nine minutes. The mixture was placed in a graduated cylinder, diluted with water to 1130 ml. and thoroughly shaken. Hydrometer readings taken at the end of 15 minutes indicated the percentage of colloids in the soil. The wilting coefficient was secured by multiplying the percentage of colloids by 0.3383.

Plant Sampling

On November 28, 1932, plant samples were taken from all plots except the one planted on the last date, October 24. The plants had not emerged on this plot. All plants on an area of 1/2500 acre were carefully removed with a trowel. Since it was impossible to secure all of the roots by this method, those adhering to the plant were cut off at the crown. Counts were then made of the number of plants and number of stools from each area. These counts gave information on the stand and stooling of the wheat on each

date of planting as it entered dormancy in the fall. Additional information was secured on the stand and stooling of the wheat on each date of planting by making culm counts at harvest time.

The green plants without roots were weighed, oven dried and then reweighed. The dried plants were analyzed for total nitrogen by the Kjeldahl process. The total amount of nitrogen per acre in the plants was calculated for each plot.

Culm counts were made at harvest as shown in Tables V and VI. The yield plots were harvested with a binder and the grain threshed with a plot thresher used for small grain experimental plot work. The test weight of the grain was determined by the official method as described by Boerner (1). Protein determinations were made on the grain by the Department of Milling Industry of the Kansas Agricultural Experiment Station. The Kjeldahl process of nitrogen analysis was used in determining the protein content of the grain.

Climatic Data

The precipitation on the 1931-1932 plots, as indicated by Table I, was sufficient throughout the crop year to

Table I. Precipitation, Agronomy Farm, 1931-1932 crop year.

Day	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1	1.95		.05			.25		.08			
2	2.30									.13	
3	.15	.01									.81
4								.02			
5	.40		4.6			.38		Tr			
6										.06	
7						.28	.07			.70	
8	4.80				.07		.17			.14	
9	1.65			.15	.17		.74			.36	
10			.7	.17	.07						
11				.51	.11						
12			.5								.1
13											.85
14				1.15		.07					
15		.03		.38					.1		
16									.36		
17	.06			.05					.4		
18	.38							.01	.26		
19		1.45						.05	.26		.4
20		.84		.47			.74		.95		1.39
21											
22		.1		.08							
23		.5		1.27							
24	.02								.14		
25									.18		
26			.21			.23				.85	.02
27				.47							.48
28									.02		
29				.03						.34	
30				.1							
31	5.2				.11					.21	
(T)	16.91	2.93	1.92	4.83	.53	1.21	1.72	.16	2.67	2.79	4.05
(N)	3.74	3.39	2.29	1.49	.86	.77	1.19	1.5	2.78	4.33	4.62

Tr - trace
(T)- total
(N)- normal, 1858-1930, inclusive

prevent damage to the plants by drouth. The large amount of precipitation in the first ten days of August and fair

amount in September provided good moisture for germination and fall growth. Extreme maximum temperatures of 97 to 104 degrees Fahrenheit and high winds the first two weeks of September killed many of the young, tender plants on the plot planted August 29. The rainfall was slightly below normal in October and December and above normal in November, January and February. The precipitation in March, 1932, was very small and in April, May and June it was slightly below normal but not enough to prevent producing a wheat crop of 65.2 bushels per acre on the highest-yielding plot.

Table II. Temperature, Manhattan, Kan. (degrees F.) (5)

Month	1931-1932 crop year		1932-1933 crop year	
	Mean	Departure from normal	Mean	Departure from normal
July	83.0	+ 4.4	82.2	+ 3.6
August	75.2	- 2.7	79.8	+ 1.9
September	78.4	+ 8.2	68.5	- 1.7
October	62.2	+ 4.7	55.3	- 2.2
November	48.2	+ 4.4	39.8	- 4.0
December	40.4	+ 9.0	28.0	- 3.4
January	28.5	0.0	39.8	+11.3
February	39.9	+ 7.4	31.1	- 1.4
March	35.8	- 8.1	45.3	+ 1.4
April	58.0	+ 3.1	55.0	+ 0.1
May	66.0	+ 1.8	65.4	+ 1.2
June	74.4	+ 0.4	83.6	+ 9.6

As indicated in Table II, the temperature during the fall of 1931 was considerably above normal. S. D. Flora (5) says, "This (July) was followed by a comparatively cool

and pleasant August and the warmest four-month period with which any year on record has closed." The temperature for the same four months in 1932, however, was below normal.

In July, 1932, Table III, the precipitation was less than half normal but was above normal in both August and September. October, November and February were all dry months while December, March and April were all slightly above normal in rainfall. The 1933 wheat crop received less than half the normal amount of rainfall in May and none in June since it was harvested before the rain of June 26. This shortage of moisture at the time the wheat was filling greatly reduced the yield of an otherwise normal or better than normal crop.

In general the season in this vicinity was favorable for the production of a good crop in the fall of 1931 and 1932. The growing season of the 1933 wheat crop was not as favorable as that of the 1932 crop. However, until the middle of May the 1933 crop was in excellent condition. During the last half of May and the first half of June, 1933, hot, dry weather hastened maturity and greatly reduced the yield.

Table III. Precipitation, Agronomy Farm, 1932-1933 crop year.

Day	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1											
2		.94	.74								
3		.04								.02	
4	.01			Tr							.73
5	.58								.58		
6									.06		
7		.52			.2			.03			
8						.02				.01	
9	.2	.25				.05		.05			
10				.22		.1					
11			.42			.09					
12		.62									.06
13		1.6								.04	.01
14											
15		.22		.2	Tr						
16											
17							.1				
18							.02				.03
19									.1	.3	
20			.73							.71	
21			.2							1.77	.05
22			1.5			.75			.03		.54
23				.15		.45			.01		
24	.15								1.04		
25	.21										
26	.08	.31									
27			.58								
28											.15
29	.69										
30										.01	
31		1.1									
(T)	1.92	5.6	4.17	.57	.2	1.46	.12	.08	1.82	2.86	1.57
(N)	4.53	3.74	3.39	2.29	1.49	.86	.77	1.19	1.5	2.78	4.33

Tr - trace
(T)- total
(N)- normal, 1858-1930, inclusive

EXPERIMENTAL RESULTS

The conclusions of investigational work on date of seeding wheat have generally included Hessian fly as a major limiting factor in early seeding and winterkilling and lack of stooling in late seeding. The earliest date on which wheat can be seeded and escape the Hessian fly has generally been considered the date on which it should be seeded. Winterkilling, deficient stand and lack of stooling have been the principal factors limiting late seeding. Other factors have largely been discarded in the discussion of the affects of time of planting.

It was the purpose of this investigation to study the relation of time of planting wheat to other factors, principally the use of the available nitrates, NO_3, stored in the seed bed. Since a study of the use of NO_3 was the principal object of this work, other limiting factors as variety, disease damage, insect damage, stand and stooling, and moisture were controlled or held constant as much as was possible in the field experiment.

Disease Damage

The diseases of wheat were not a limiting factor on

any of the plots in either of the two years of this experiment.

Loose smut, Ustilago tritici, and bunt or stinking smut, Tilletia tritici, were both eliminated as a factor by using seed free from infection. Leaf rust, Puccinia triticina, was present to a limited extent each year but the infection was so slight and uniform on all plots that it probably did not affect the comparative yields.

Insect Damage

The only insect that influenced the results secured in this experiment was the Hessian fly, Phytophaga destructor (Say). As shown in Table IV, plots planted early in the fall of 1931 had a high Hessian fly infestation. Forty-two per cent of the plants and 7.33 per cent of the tillers on the plot planted August 29 were infested in December, 1931. At this time some plants, infested early in the fall, had disintegrated. The infestation of both plants and tillers was higher on the plot planted September 14 than on the one planted August 29 when the December count was made. The plots planted on the two earliest dates, August 29 and September 14, 1931, were so heavily infested that the yield would be influenced according to

Table IV. Hessian fly infestation of plants and tillers on wheat plots.

Date planted	Variety	Plants Total	Plants Inf.	Plants % Inf.	Total fly	Tillers Total	Tillers Inf.	Tillers % Inf.	Average number of fly per infested plant
		Fly count made December, 1931							
Aug. 29	Kanred	100	42	42.0	79	556	43	7.33	1.88
Sept. 14	"	100	58	58.0	126	624	59	9.45	2.17
Sept. 29	"	100	13	13.0	17	564	13	2.30	1.29
Oct. 6	"	100	4	4.0	5	496	4	0.80	1.25
Oct. 17	"	100	0	0.0	0	294	0	0.0	0.0
		Fly count made October 21, 1932							
Aug. 27	Kawvale	50	16	32.0	44	439	23	5.2	2.7
Sept. 5	"	50	2	4.0	2	258	2	0.7	1.0

Dr. R. H. Painter, entomologist, Kansas Agricultural Experiment Station. The Hessian fly, therefore, was probably so great a factor in the yields of 1932 that it would be difficult to determine the influence of other factors. In order to eliminate the Hessian fly as much as possible, the Kawvale variety was seeded on the 1932-1933 plots.

The results of Hessian fly "counts" made on the 1932-1933 plots are given in Table IV. While 32 per cent of the plants and 5.2 per cent of the tillers of the plot planted August 27 were infested, the injury to the plants was very slight due to the failure of fly to seriously injury Kawvale according to Dr. R. H. Painter.

Painter, Salmon and Parker (14) found an average Hessian fly infestation in Kawvale of 1.9 per cent of plants and 39.7 per cent in Kanred over a four-year period. They also show that the flaxseed and larvae are small, shriveled and misshapen on Blackhull but plump and well developed on Kanred although the eggs were deposited by the same female. Doctor Painter says that the poor development of fly found on Blackhull is found also on Kawvale. This explains the failure of the 32 per cent infestation to produce effective injury on the plot of Kawvale seeded August 27.

Because of the fact that the data secured in 1931-1932

were subject to question on account of Hessian fly infestation and that this factor was eliminated in the 1932-1933 data, the majority of the discussion of results will be based on the 1932-1933 data.

Stand and Stooling

Data on stand and stooling were secured, in 1932, by removing all plants from an area of 1/2500 acre from each plot on November 28, 1932. It was considered that the wheat had entered dormancy at this time and that there would be no further stooling until spring. After the plants were removed from the soil, they were counted and the number of stools determined. The culms were counted at harvest.

In 1931 no definite counts were made to determine the stand secured in the fall but culm counts were made at harvest. These data given in Table V, express the differences in stand and stooling in the early, medium and late-sown plots. Many of the plants on the plot sown August 29, 1931, were killed apparently by high temperature and wind or Hessian fly before they became established. This, no doubt, decreased the yield. The wheat on the plot planted on September 14 maintained a good uniform stand but failed to reach the height of other plots as indicated by the

comparatively large number of culms and small yield of straw as given in Table V. This stunting of plants may have been caused principally by the high infestation of Hessian fly as before mentioned.

Table V. Relation of yield of wheat planted on various dates to stand and stooling, 1931-1932.

Date of seeding	Yield Bu. per A.	Number of culms per acre	Weight of straw lbs. per acre
Aug. 29	46.2	2,582,000	3,369
Sept. 14	52.1	4,457,000	2,686
Sept. 29	60.1	4,346,000	4,359
Oct. 6	65.2	4,752,000	4,199
Oct. 17	61.4	4,816,000	3,357
Oct. 24	45.6	3,562,000	3,742
Oct. 31	36.1	3,101,000	3,898

In the fall of 1932, a nearly uniform stand was secured on all of the first six seeding dates as indicated by the number of plants per acre given in Table VI. The wheat on the plot planted October 24 did not emerge until spring. While the number of plants on the plot planted October 10 was practically the same as on the plot planted September 22, the yield was only one-third as much. The low stooling as indicated by both the November 28 count and the harvest culm count no doubt greatly decreased the yield of the October 10 plot.

A study of the number of stools as indicated by the November 28 count and the harvest culm count in Table VI

shows that the number on the plots planted before the date of maximum yield is less at harvest than on November 28, while on the plots planted on and after the date of maximum yield the opposite is true. The loss of stools in the earlier-seeded plots was apparently due to winterkilling. This fact will be referred to later.

Table VI. Relation of yield of wheat planted on various dates to stand and stooling, 1932-1933.

Date of seeding	Yield Bu. per A.	No. culms per acre	No. plants per acre Nov. 28	No. stools per acre Nov. 28
Aug. 27	23.5	2,252,000	557,500	3,407,000
Sept. 5	34.0	2,691,000	510,000	3,352,000
" 13	39.4	2,897,000	582,500	3,625,000
" 22	48.1	2,987,000	517,500	2,792,000
" 26	40.5	2,488,000	495,000	2,200,000
Oct. 10	16.8	1,774,000	510,000	510,000
" 24	4.2	965,000	.... Wheat not up	...

The relation of yield to culm count is shown in Fig. 2. This curve indicates that the plants on the early-sown plots were not able to take advantage of the large number of culms to produce wheat. As the date of planting approaches the date of maximum yield, September 22, the yield increases more rapidly than the culm count, indicating the elimination to some extent at least of other factors. After the date of maximum yield is reached, the yield falls off in almost perfect correlation with the reduction in stooling as indicated by culm count. Therefore, it would

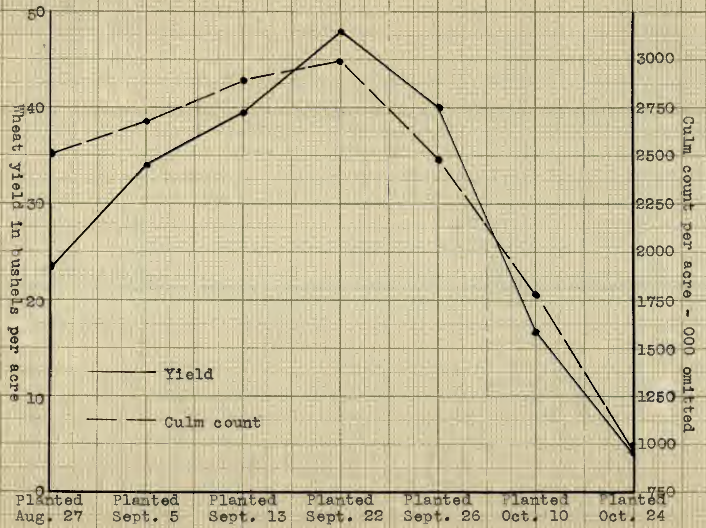

Fig. 2. Relation of culm count and yield of grain on wheat plots, planted in 1932, on dates indicated.

appear that the failure of the plants to stool in the later-seeded plots, exerted a dominating influence on the ability to yield.

Relation of Moisture to Yield

During the time that this work was in progress a careful check was kept on the amount of moisture in the soil on the plots seeded at various dates. Tables VII, VIII, X and XI give the total soil moisture and the amount of available moisture in the first, second and third foot sections at each sampling. The available moisture was determined by subtracting the wilting coefficient, as determined by the hydrometer method, from the total moisture. The wilting coefficient determined on a composite of six borings for each layer was found to be 12.4 per cent in the surface foot, 17.4 per cent in the second foot, and 16.3 per cent in the third.

The moisture on the plots in the fall of 1931 as shown in Table VII varied to some extent on September 14, the date that all plots were sampled. This difference was probably due to the fact that the first plot had been disked to kill volunteer oats and had been worked with the drill at planting, thus leaving it more open for the

5.2-inch rain of August 31 to enter the soil. By October 31, the moisture was quite uniform over the entire series.

The moisture on August 27, 1932, which was the first date of sampling, was very uniform on all plots as indicated in Table X. There was approximately three per cent more moisture in the soil in the fall of 1932 than in 1931. The heavier growth of wheat on the early-planted plots reduced the moisture more than on the later-planted ones, although the difference was not great.

Tables VIII and XI give the percentage of available moisture in each foot section at the time of sampling. These data show that the moisture was reduced to the wilting coefficient or the point where it could not be used by the plant in only a few instances. It must be recognized, however, that on May 21, 1932, and May 19, 1933, the moisture had been reduced to a point that a plant might suffer because it would not secure moisture sufficiently fast to maintain turgidity in the plants. This condition probably greatly reduced the yield of the 1933 crop when the temperature of June averaged 9.6 degrees F. above normal, with practically no addition by rainfall to the soil moisture present on May 19. However, it will also be observed that on May 21, 1932, (Table IX), all plots were reduced to

practically the same moisture content and on May 19, 1933 (Table XII), the plot planted on September 22, which made the highest yield, had the least available water.

Fig. 3 expresses graphically the yield and available moisture at three periods, November 28, 1932, when wheat was entering dormancy for the winter; March 3, 1933, when it emerged from dormancy; and May 19, 1933, when it headed. This chart shows that all plots were well supplied with moisture on November 28 and March 3. It also shows that when the moisture was low the highest-yielding plot, which was planted September 22, had as little or less available moisture than any one of the three plots planted before September 22. It, therefore, appears probable that the lack of moisture did not reduce the yield of the plots planted on August 27, September 5 or September 13 any more than it did the yield of the plot planted September 22.

Relation of Date of Seeding to Yield

It is well known that wheat may be seeded too early or too late to secure the highest yields. This is indicated also by the results of this experiment as shown in Fig. 4. The yields on the plots for both 1932 and 1933 are noticeably lower on the early and on the late-seeded plots

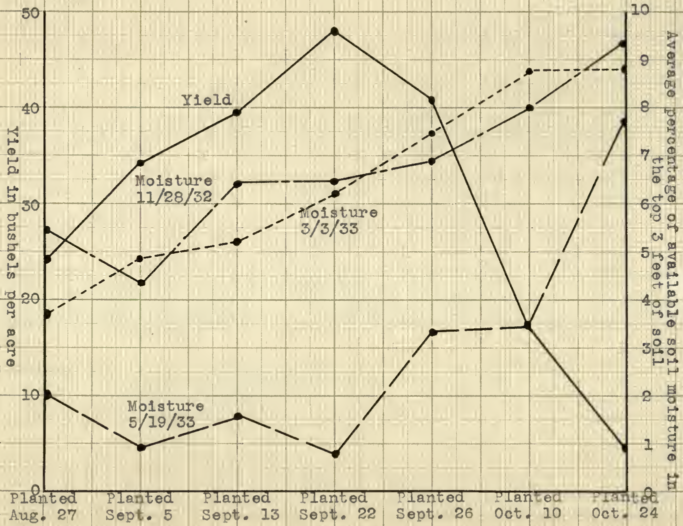

Fig. 3. Relation of yield, 1933, and available soil moisture on Nov. 28, 1932
March 3, 1933, and May 19, 1933, on wheat plots planted on dates indicated.

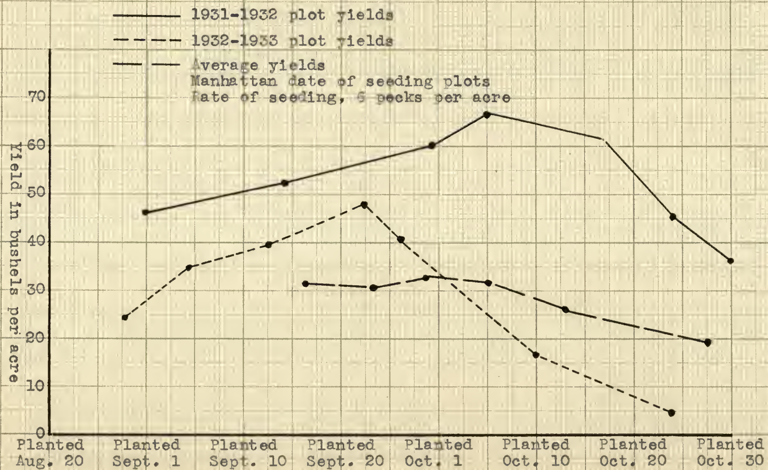

Fig. 4. Relation of yield to date of planting.

Table VII. Soil moisture, 1931-1932.

Date planted & depth	Percentage of soil moisture on date indicated (oven-dry basis)									
	Sept. 14	Sept. 29	Oct. 6	Oct. 17	Oct. 24	Oct. 31	Apr. 15	Apr. 26	May 21	June 6
Aug. 29										
1 ft.	23.5	24.6	20.7	22.2	18.7	18.9	14.1	----	11.0	18.2
2 "	25.0	26.9	26.4	24.8	24.9	27.2	23.9	----	19.6	22.5
3 "	19.0	21.0	18.2	18.7	17.9	21.5	22.1	----	18.3	20.9
Sept. 14										
1 ft.	20.6	25.0	22.4	22.3	18.7	18.8	14.5	----	11.5	21.3
2 "	21.8	27.1	25.9	26.2	26.1	24.3	24.2	----	19.0	22.7
3 "	19.1	20.9	22.1	23.1	22.7	20.7	22.1	----	17.8	21.5
Sept. 29										
1 ft.	19.7	24.0	24.0	23.8	20.7	22.1	14.0	----	11.3	19.1
2 "	22.2	22.4	26.6	27.2	24.8	25.3	21.8	----	19.6	22.8
3 "	22.5	22.8	21.2	18.3	17.5	21.8	19.0	----	17.6	20.2
Oct. 6										
1 ft.	18.9	----	22.8	23.7	21.5	20.9	13.4	----	10.2	19.8
2 "	22.2	----	22.1	23.7	23.3	25.9	24.3	----	19.6	19.9
3 "	17.2	----	16.8	17.6	19.0	17.6	22.7	----	18.3	19.2
Oct. 17										
1 ft.	18.6	----	----	23.8	21.9	21.2	15.3	21.3	12.0	18.2
2 "	21.6	----	----	26.5	27.6	25.9	24.2	23.9	20.6	21.0
3 "	16.0	----	----	19.1	23.1	19.9	22.8	22.2	19.0	19.9
Oct. 24										
1 ft.	18.8	----	----	----	22.5	21.9	14.8	23.0	10.3	16.2
2 "	20.0	----	----	----	25.8	26.4	25.2	22.2	19.3	20.9
3 "	16.9	----	----	----	19.8	20.3	24.0	21.9	19.5	21.9
Oct. 31										
1 ft.	18.2	----	----	----	----	21.0	15.6	22.4	11.6	19.9
2 "	20.2	----	----	----	----	25.5	25.6	22.8	19.0	20.4
3 "	16.5	----	----	----	----	19.3	24.3	23.5	19.8	23.4
Fallow										
1 ft.		----	----	----	----	21.0	----	24.7	----	----
2 "		----	----	----	----	25.5	----	25.0	----	----
3 "		----	----	----	----	19.3	----	24.0	----	----

Table VIII. Soil moisture, 1931-1932.

Date planted & depth	Percentage of available soil moisture on date indicated									
	Sept. 14	Sept. 29	Oct. 6	Oct. 17	Oct. 24	Oct. 31	Apr. 15	Apr. 26	May 21	June 6
Aug. 29										
1 ft.	11.1	12.2	8.3	9.8	6.3	6.5	1.7	----	-1.4	5.8
2 "	7.6	9.5	9.0	7.4	7.5	9.8	6.5	----	2.2	5.1
3 "	2.7	4.7	1.9	2.4	1.6	5.2	5.8	----	2.0	4.6
Sept. 14										
1 ft.	8.2	12.6	10.0	9.9	6.3	6.4	2.1	----	-0.9	8.9
2 "	4.4	9.7	8.5	8.8	8.7	6.9	6.8	----	1.6	5.3
3 "	2.8	4.6	5.8	6.8	6.4	4.4	5.8	----	1.5	5.2
Sept. 29										
1 ft.	7.3	11.6	11.6	11.4	8.3	9.7	1.6	----	-1.1	6.7
2 "	4.8	5.0	9.2	9.8	7.4	7.9	4.4	----	2.2	5.4
3 "	6.2	6.5	4.9	2.0	1.2	5.5	2.7	----	1.3	3.9
Oct. 6										
1 ft.	6.5	----	10.4	11.3	9.1	8.5	1.0	----	-2.2	7.4
2 "	4.8	----	4.7	6.3	5.9	8.5	6.9	----	2.2	2.5
3 "	0.9	----	0.5	1.3	2.7	1.3	6.4	----	2.0	2.9
Oct. 17										
1 ft.	6.2	----	----	11.4	9.5	8.8	2.9	8.9	-0.4	5.8
2 "	4.2	----	----	9.1	10.2	3.5	6.8	6.5	3.2	3.6
3 "	-0.3	----	----	2.8	6.8	3.6	6.5	5.9	2.7	3.6
Oct. 24										
1 ft.	6.4	----	----	----	10.1	9.5	2.4	10.6	-2.1	3.8
2 "	2.6	----	----	----	8.4	9.0	7.8	4.8	1.9	3.5
3 "	0.6	----	----	----	3.5	4.0	7.7	5.6	3.2	5.6
Oct. 31										
1 ft.	5.8	----	----	----	----	8.6	3.2	10.0	-2.1	7.5
2 "	2.8	----	----	----	----	8.1	8.2	5.4	1.9	3.0
3 "	0.2	----	----	----	----	3.0	8.0	7.2	3.2	7.1
Fallow										
1 ft.	----	----	----	----	----	8.6	----	12.3	----	----
2 "	----	----	----	----	----	8.1	----	7.6	----	----
3 "	----	----	----	----	----	3.0	----	7.7	----	----

Table IX. Summary of soil moisture, 1931-1932.

Date planted	Sept. 14	Sept. 29	Oct. 6	Oct. 17	Oct. 24	Oct. 31	Apr. 15	Apr. 26	May 21	June 6
	Average percentage of moisture in top three feet of soil, on dates indicated									
Aug. 29	22.3	24.2	21.8	21.9	20.5	22.5	20.0	----	16.3	20.5
Sept. 14	20.5	24.3	23.5	23.9	22.5	21.3	20.3	----	16.1	21.8
Sept. 29	21.5	23.1	23.9	23.1	21.0	23.1	18.3	----	16.2	20.7
Oct. 6	19.4	----	20.6	21.7	21.3	21.5	20.1	----	16.0	19.6
Oct. 17	18.7	----	----	23.1	24.3	22.3	20.8	22.5	17.2	19.7
Oct. 24	18.6	----	----	----	22.7	22.9	21.3	22.4	16.4	19.7
Oct. 31	18.3	----	----	----	----	21.9	21.8	22.9	16.8	21.2
Fallow	----	----	----	----	----	21.9	----	24.6	----	----
	Average percentage of available moisture in top three feet of soil, on dates indicated									
Aug. 29	7.1	8.8	6.4	6.5	5.1	7.2	2.7	----	0.9	5.2
Sept. 14	5.1	9.0	8.1	8.5	7.1	5.9	4.9	----	0.7	6.5
Sept. 29	6.1	7.7	8.6	7.7	5.6	7.7	3.9	----	0.8	5.3
Oct. 6	4.1	----	5.2	6.3	5.9	6.1	4.8	----	0.7	4.3
Oct. 17	3.4	----	----	7.0	8.8	7.0	5.4	7.1	1.8	4.3
Oct. 24	3.2	----	----	----	7.3	7.5	6.0	7.0	1.0	4.3
Oct. 31	2.9	----	----	----	----	6.6	6.5	7.5	1.0	5.9
Fallow	----	----	----	----	----	6.6	----	9.2	----	----

Table X. Soil moisture, 1932-1933.

Date planted & depth	Percentage of soil moisture on date indicated (oven-dry basis) Aug. 27	Sept. 5	Sept. 13	Sept. 22	Sept. 26	Oct. 10	Oct. 24	Nov. 28	Mar. 3	May 19
Aug. 27										
1 ft.	23.4	24.6	25.0	26.9	23.7	20.4	14.7	16.5	17.5	12.9
2 "	25.0	28.4	28.5	26.7	27.5	25.8	22.4	23.1	20.2	20.1
3 "	22.1	22.4	24.6	23.0	23.3	22.7	22.7	22.1	19.3	19.2
Sept. 5										
1 ft.	23.4	25.3	25.6	27.4	24.5	21.5	16.8	17.1	18.2	13.4
2 "	25.3	26.7	28.7	28.5	27.5	26.5	24.7	22.5	21.5	18.9
3 "	21.9	22.2	24.3	21.3	23.7	23.4	23.1	21.5	20.7	18.1
Sept. 13										
1 ft.	23.4	----	26.5	28.4	25.3	23.0	17.5	17.6	18.2	13.1
2 "	23.4	----	29.1	27.8	27.7	26.4	25.0	24.6	22.5	19.3
3 "	19.0	----	23.9	23.6	22.2	24.5	21.3	23.1	21.0	18.7
Sept. 22										
1 ft.	23.6	----	----	29.2	24.8	23.1	19.3	16.9	19.5	12.3
2 "	24.6	----	----	28.5	27.8	26.9	26.9	25.3	23.7	17.7
3 "	20.1	----	----	23.6	24.6	23.6	24.5	23.3	21.8	18.2
Sept. 26										
1 ft.	23.1	----	----	----	25.2	23.6	20.0	17.3	19.6	14.1
2 "	25.5	----	----	----	27.2	27.2	25.8	25.9	24.3	21.5
3 "	20.0	----	----	----	20.7	22.7	23.7	23.6	24.3	20.3
Oct. 10										
1 ft.	23.6	----	----	----	----	24.3	25.6	20.7	21.8	14.6
2 "	24.5	----	----	----	----	27.2	29.1	26.5	26.5	20.7
3 "	19.3	----	----	----	----	22.5	25.5	22.8	24.0	20.9
Oct. 24										
1 ft.	23.0	----	----	----	----	----	24.7	22.4	22.5	18.9
2 "	25.6	----	----	----	----	----	26.7	27.5	25.9	25.8
3 "	20.7	----	----	----	----	----	25.0	24.3	24.2	24.7
Fallow										
1 ft.	----	----	----	----	----	----	----	22.4	22.5	25.8
2 "	----	----	----	----	----	----	----	27.5	25.8	27.5
3 "	----	----	----	----	----	----	----	24.3	23.4	24.3

Table XI. Soil moisture, 1932-1933.

Date planted & depth	Aug. 27	Sept. 5	Sept. 13	Sept. 22	Sept. 26	Oct. 10	Oct. 24	Nov. 28	Mar. 3	May 19
	Percentage of available soil moisture on date indicated									
Aug. 27										
1 ft.	11.0	12.2	12.6	14.5	11.3	8.0	2.3	4.1	5.1	0.5
2 "	7.6	11.0	11.1	9.3	10.1	8.4	5.0	5.7	2.8	2.7
3 "	5.8	6.1	8.3	6.7	7.0	6.4	6.4	5.8	3.0	2.9
Sept. 5										
1 ft.	11.0	12.9	13.2	15.0	12.1	9.1	4.4	2.7	5.8	1.0
2 "	7.9	9.3	11.3	11.1	10.1	9.1	7.3	5.1	4.1	1.5
3 "	5.6	5.9	8.0	5.0	7.4	7.1	6.8	5.2	4.4	1.8
Sept. 13										
1 ft.	11.0	----	14.1	16.0	12.9	10.6	5.1	5.2	5.8	0.7
2 "	6.0	----	11.7	10.4	10.3	9.0	7.6	7.2	5.1	1.9
3 "	2.7	----	7.6	7.3	5.9	8.2	5.0	6.8	4.7	2.4
Sept. 22										
1 ft.	11.2	----	----	16.8	12.4	10.7	6.9	4.5	7.1	-0.1
2 "	7.2	----	----	11.1	10.4	9.5	9.5	7.9	6.3	0.3
3 "	3.8	----	----	7.3	8.3	7.3	8.2	7.0	5.5	1.9
Sept. 26										
1 ft.	10.7	----	----	----	12.8	11.2	7.6	4.9	7.2	1.7
2 "	8.1	----	----	----	9.8	9.8	8.4	8.5	6.9	4.1
3 "	3.7	----	----	----	4.4	6.4	7.4	7.3	8.0	4.0
Oct. 10										
1 ft.	11.2	----	----	----	----	11.9	13.2	8.3	9.4	2.2
2 "	7.1	----	----	----	----	9.8	11.7	9.1	9.1	3.3
3 "	3.0	----	----	----	----	6.2	9.2	6.5	7.7	4.6
Oct. 24										
1 ft.	10.6	----	----	----	----	----	12.3	10.0	10.1	6.5
2 "	8.2	----	----	----	----	----	9.3	10.1	8.5	8.4
3 "	4.4	----	----	----	----	----	8.7	8.0	7.9	8.4
Fallow										
1 ft.	----	----	----	----	----	----	----	10.0	10.1	13.4
2 "	----	----	----	----	----	----	----	10.1	8.4	10.1
3 "	----	----	----	----	----	----	----	8.0	7.1	8.0

Table XII. Summary of soil moisture, 1932-1933.

Date planted	Aug. 27	Sept. 5	Sept. 13	Sept. 22	Sept. 26	Oct. 10	Oct. 24	Nov. 28	Mar. 3	May 19
	Average percentage of moisture in top three feet of soil, on dates indicated									
Aug. 27	23.5	23.1	26.0	25.5	24.8	22.7	19.9	20.6	19.0	17.4
Sept. 5	23.5	24.7	26.2	25.7	25.2	23.8	21.2	20.4	20.1	16.8
Sept. 13	21.9	----	26.3	26.6	25.1	24.6	21.3	21.8	20.6	17.0
Sept. 22	22.8	----	----	27.1	25.7	24.5	23.2	21.8	21.7	16.1
Sept. 26	22.9	----	----	----	24.4	24.5	23.2	22.3	22.7	18.6
Oct. 10	22.5	----	----	----	----	24.7	26.7	23.2	24.1	18.7
Oct. 24	23.1	----	----	----	----	----	25.5	23.7	24.2	23.1
Fallow	----	----	----	----	----	----	----	24.7	23.9	25.9
	Average percentage of available moisture in top three feet of soil, on dates indicated									
Aug. 27	8.1	9.8	10.7	10.2	9.5	7.6	4.6	5.2	3.6	2.0
Sept. 5	8.2	9.3	10.8	10.4	9.9	8.4	6.2	4.3	4.8	1.4
Sept. 13	6.6	----	11.1	11.2	9.7	9.3	5.9	6.4	5.2	1.7
Sept. 22	7.4	----	----	11.7	10.4	9.2	8.2	6.4	6.3	0.7
Sept. 26	7.5	----	----	----	9.0	9.1	7.8	6.9	7.4	3.3
Oct. 10	7.1	----	----	----	----	9.3	11.3	8.0	8.7	3.4
Oct. 24	7.7	----	----	----	----	----	10.1	9.4	8.8	7.8
Fallow	----	----	----	----	----	----	----	9.4	8.5	10.5

Table XIII. Relation of available soil moisture on various dates to yield of wheat planted on seven dates in 1931 and in 1932.

Date of seeding	Yield Bu. per A.	Average percentage of available soil moisture in first three feet of soil: at seeding	Oct. 31	Apr. 15	May 21	June 6
		1931 - 1932				
Aug. 29	46.2	----	7.2	2.7	0.9	5.2
Sept. 14	52.1	5.1	5.9	4.9	0.7	6.5
Sept. 29	60.1	6.1	7.7	2.9	0.8	5.3
Oct. 6	65.2	4.1	6.1	4.8	0.7	4.3
Oct. 17	61.4	3.4	7.0	5.4	1.8	4.3
Oct. 24	45.6	3.2	7.5	6.0	1.0	4.3
Oct. 31	36.1	2.9	6.6	6.5	1.0	5.9
Fallow	----	----	6.6	---	---	---
		1932 - 1933				
		at seeding	Nov. 28	Mar. 3	May 19	
Aug. 27	23.5	8.1	5.2	3.6	2.0	
Sept. 5	34.0	9.3	4.3	4.8	1.4	
Sept. 13	39.4	11.1	6.4	5.2	1.7	
Sept. 22	48.1	11.7	6.4	6.3	0.7	
Sept. 26	40.5	9.0	6.9	7.4	3.3	
Oct. 10	16.8	9.3	8.0	8.7	3.4	
Oct. 24	4.2	10.1	9.4	8.8	7.8	
Fallow	----	----	9.4	8.5	10.5	

than on the plots seeded at an intermediate date. The wheat on these plots was sown at a rate of five pecks per acre.

The difference in date of highest yield in the two years is readily understood by studying the temperatures given in Table II. The temperature of September, October, November and December, 1931, averaged 6.5 degrees F. above normal. That of the same four months in 1932 averaged 2.8 degrees F. below normal. This gave the later-planted plots in 1931 an advantage over the early-planted plots. Wheat did not stop growing in the fall of 1931 until about January 1, while it stopped noticeable growth about the first of December in 1932.

The results of this experiment agree with the results from the date-of-seeding experiments of the Kansas Agricultural Experiment Station, at Manhattan, as shown in Fig. 4. The average yields secured in the date-of-seeding experiments are uniformily high from wheat planted September 16 to October 6. The highest yields were secured in this experiment from wheat planted October 6, 1931, and September 22, 1932.

Relation of Date of Seeding to Supply of Nitrate

The food value of wheat is due in a large measure to its protein, the essential and characteristic element of which is nitrogen. The value of wheat, therefore, is closely related to the ability of the plant to secure nitrogen and to use it in building up the proteins in the grain. Call (2) points out that at Manhattan, nitrogen in the form of nitrates is one of the principal limiting factors in wheat production.

An adequate supply of NO_3 in the soil is necessary for a large yield of high protein wheat. The problem to be considered now is whether or not varying the supply of NO_3 at different stages of plant development will make a difference in the amount or the protein content of the grain produced.

The NO_3 content in the soil under winter wheat in the spring may be varied by (a) the addition of nitrogen fertilizer at various stages of growth or (b) by controlling the use of NO_3 by the plant through variation in planting dates. Davidson and LeClerc (4) applied nitrogen when the (a) plant was two inches high, (b) at the time of heading, and (c) at the milk stage. They found that only those plots that received the nitrate at the first stage of growth

responded in yield to the application of fertilizer. They also found that the sample grown on the plots which received an application of Na NO_3 in the second stage gave by far the highest protein content and the lowest percentage of yellow berry. Gericke (6) in California, Davidson (3) at College Park, Maryland, and Dr. F. L. Duley, in unpublished data obtained at Manhattan, found the same relationship.

A difference in the response of the wheat plant to the application of nitrogen fertilizers at various growth stages suggests the possibility of similar differences in the response with variations in the amount of soil NO_3 through control of the use of the nitrogen supply. This problem was studied by tracing the supply of NO_3 in the soil throughout the life of the plant and observing the affect on the resultant crop. Table XIV gives the p.p.m. of NO_3 in the top three feet of soil on seven wheat plots planted at different dates in the fall of 1931 and one fallow plot. The plots planted August 29 and September 14 have a larger amount of NO_3 in the top foot than the other plots on September 14. This is probably due to the fact that these plots were higher in moisture probably caused by a disking to kill volunteer oats prior to time of the August 31 rain.

Table XIV. Soil nitrates (NO_3), 1931-1932.

Date planted & depth	p.p.m., NO_3, of oven-dry soil, on date indicated								
	Sept. 14	Sept. 29	Oct. 6	Oct. 17	Oct. 24	Oct. 31	Apr. 15	Apr. 26	June 6
Aug. 29									
1 ft.	109.4	71.7	81.6	73.1	80.7	63.6	12.3	----	5.8
2 "	43.3	53.8	45.1	37.6	65.6	60.3	20.2	----	4.8
3 "	29.4	42.1	18.1	25.1	22.5	32.1	19.6	----	4.5
Sept. 14									
1 ft.	106.6	65.8	52.2	42.6	41.4	21.8	7.7	----	5.0
2 "	45.1	50.6	30.4	18.5	24.4	17.5	6.9	----	4.3
3 "	29.0	36.1	23.8	18.2	28.4	12.9	6.7	----	4.1
Sept. 29									
1 ft.	92.2	70.5	60.8	47.8	93.9	35.6	5.6	----	4.1
2 "	39.2	40.0	24.5	34.3	27.6	31.8	5.7	----	3.6
3 "	35.4	39.9	27.5	18.3	17.5	15.2	6.7	----	4.5
Oct. 6									
1 ft.	74.7	----	59.4	81.7	111.4	65.8	6.3	----	4.0
2 "	47.6	----	37.1	35.8	45.0	29.7	10.1	----	5.7
3 "	29.5	----	17.2	14.3	39.7	10.0	8.9	----	4.5
Oct. 17									
1 ft.	75.8	----	----	82.2	122.3	87.9	6.9	5.0	4.5
2 "	32.2	----	----	38.3	34.2	26.9	11.3	4.6	3.8
3 "	19.3	----	----	16.5	23.6	11.0	11.3	4.7	3.9
Oct. 24									
1 ft.	93.3	----	----	----	58.7	75.8	7.3	8.7	4.1
2 "	54.0	----	----	----	52.4	25.3	20.9	12.1	3.6
3 "	52.0	----	----	----	24.4	17.0	24.7	16.3	4.1
Oct. 31									
1 ft.	84.8	----	----	----	----	85.1	8.4	4.7	5.8
2 "	42.4	----	----	----	----	27.9	12.5	7.3	5.1
3 "	21.6	----	----	----	----	9.0	16.0	9.1	3.8
Fallow									
1 ft.	119.0	----	----	----	----	85.1	----	38.6	----
2 "	64.6	----	----	----	----	27.9	----	41.1	----
3 "	24.3	----	----	----	----	9.0	----	28.3	----

The plot planted on August 29 had a higher amount of NO_3 throughout the life of the crop than the plot planted September 14. This was probably because many of the plants on the August 29 plot were killed early. The resultant thin stand, shown in Table V, failed to use the NO_3 as rapidly as did the thicker stand on the plot planted September 14. This difference is outstanding in the October 31 sampling.

In order to have these data in a form more usable, the pounds of NO_3 per acre were calculated, by using 3,600,000, 3,800,000 and 4,000,000 pounds as the weight of an acre foot of soil in the first, second and third foot levels, respectively. These data are given in Table XV.

The parts per million and pounds per acre of NO_3 in the first three feet of soil are given for each plot planted in the fall of 1932 in Tables XVI and XVII, respectively. The amount of NO_3 in all plots on August 27, 1932, was more uniform than on the 1931 plots as found in the September 14, 1931, sampling. The amount of NO_3 on the early-planted plots was less than that on the later-planted plots in all samplings after October 10. This greater reduction in the early-planted plots was probably caused by the heavier growth of wheat and may be accounted for by the actual use of NO_3 by the plant, possibly supplemented by the inhibition of nitrate formation by the wheat plant. Lyon, Bizell and

Table XV. Soil nitrates (NO_3), 1931-1932.

Date planted & depth	Pounds of NO_3 per acre on date indicated: Sept. 14	Sept. 29	Oct. 6	Oct. 17	Oct. 24	Oct. 31	Apr. 15	Apr. 26	June 6
Aug. 29									
1 ft.	393.8	258.1	293.8	263.2	290.5	228.9	44.3	----	20.9
2 "	164.5	204.4	171.4	142.9	249.3	229.1	76.8	----	19.2
3 "	117.6	168.4	72.4	100.4	90.0	128.4	78.4	----	18.0
Sept. 14									
1 ft.	383.8	236.9	187.9	153.4	149.0	78.5	27.7	----	18.0
2 "	171.4	192.3	115.5	70.3	92.7	66.5	26.2	----	16.3
3 "	116.0	144.4	95.2	72.8	113.6	51.6	26.8	----	16.4
Sept. 29									
1 ft.	331.9	253.8	218.9	172.1	338.0	128.2	20.2	----	14.8
2 "	149.0	152.0	93.1	130.3	104.9	120.8	21.7	----	13.7
3 "	141.6	159.6	110.0	73.2	70.0	60.8	26.8	----	18.0
Oct. 6									
1 ft.	268.9	----	213.8	294.1	401.0	236.9	22.7	----	14.4
2 "	180.9	----	141.0	136.0	171.0	112.9	38.4	----	21.7
3 "	118.0	----	68.8	57.2	158.8	40.0	35.6	----	13.0
Oct. 17									
1 ft.	272.9	----	----	295.9	440.3	316.4	24.8	18.0	16.2
2 "	122.4	----	----	145.5	130.0	102.2	42.9	17.5	14.4
3 "	77.2	----	----	66.0	94.4	44.0	45.2	18.8	15.6
Oct. 24									
1 ft.	335.9	----	----	----	211.3	272.9	26.3	31.3	14.8
2 "	205.2	----	----	----	199.1	96.1	79.4	46.0	13.7
3 "	208.0	----	----	----	97.6	68.0	98.8	65.2	16.4
Oct. 31									
1 ft.	305.3	----	----	----	----	306.4	30.2	16.9	20.9
2 "	161.1	----	----	----	----	106.0	47.5	27.7	19.4
3 "	86.4	----	----	----	----	36.0	64.0	36.4	15.2
Fallow									
1 ft.	428.4	----	----	----	----	306.4	----	139.0	----
2 "	245.5	----	----	----	----	106.0	----	156.2	----
3 "	97.2	----	----	----	----	36.0	----	113.2	----

Table XVI. Soil nitrates (NO_3), 1932-1933.

Date planted & depth	p.p.m., NO_3, of oven-dry soil, on date indicated									
	Aug. 27	Sept. 5	Sept. 13	Sept. 22	Sept. 26	Oct. 10	Oct. 24	Nov. 28	Mar. 3	May 19
Aug. 27										
1 ft.	56.4	51.8	42.0	50.1	53.6	17.3	11.4	13.7	2.1	2.8
2 "	11.4	40.6	19.5	33.0	40.2	19.1	6.7	10.0	1.4	T
3 "	6.6	15.0	9.9	21.3	24.8	9.7	5.5	9.1	1.1	T
Sept. 5										
1 ft.	37.1	55.5	37.5	58.2	53.9	25.6	22.6	12.0	2.7	3.4
2 "	11.6	21.2	20.9	34.9	39.1	27.8	17.6	14.8	2.8	T
3 "	8.3	7.4	9.4	19.0	25.1	11.6	8.5	10.7	2.2	T
Sept. 13										
1 ft.	46.4	----	57.3	55.8	55.5	49.1	28.7	10.7	5.7	2.0
2 "	9.1	----	25.5	35.1	45.2	31.4	20.7	14.2	5.5	T
3 "	7.0	----	12.5	18.8	29.6	11.8	7.0	16.0	3.5	T
Sept. 22										
1 ft.	41.1	----	----	59.8	65.0	51.4	51.3	34.2	31.8	2.9
2 "	9.2	----	----	37.1	38.0	28.8	31.5	21.2	21.4	T
3 "	6.3	----	----	21.4	29.3	10.6	12.5	10.3	7.2	T
Sept. 26										
1 ft.	41.6	----	----	----	61.8	64.2	69.3	44.5	36.4	2.2
2 "	16.1	----	----	----	25.1	27.6	27.0	38.1	32.7	1.9
3 "	9.6	----	----	----	13.5	9.4	10.3	37.6	24.2	T
Oct. 10										
1 ft.	35.6	----	----	----	----	73.5	60.0	63.8	36.4	2.1
2 "	15.5	----	----	----	----	21.0	25.4	29.4	32.7	1.6
3 "	9.4	----	----	----	----	9.4	10.1	16.3	24.2	T
Oct. 24										
1 ft.	35.7	----	----	----	----	----	58.2	63.8	73.0	20.7
2 "	15.3	----	----	----	----	----	22.4	29.4	31.5	32.8
3 "	9.9	----	----	----	----	----	9.6	16.3	6.8	12.4
Fallow										
1 ft.	----	----	----	----	----	----	----	68.8	70.7	60.1
2 "	----	----	----	----	----	----	----	26.6	21.2	36.9
3 "	----	----	----	----	----	----	----	9.4	6.7	13.2

T indicates trace

Table XVII. Soil nitrates (NO_3), 1932-1933.

Date planted & depth	Pounds of NO_3 per acre on date indicated									
	Aug. 27	Sept. 5	Sept. 13	Sept. 22	Sept. 26	Oct. 10	Oct. 24	Nov. 28	Mar. 3	May 19
Aug. 27										
1 ft.	203.0	186.5	151.2	180.4	193.0	62.3	41.0	40.3	7.6	10.0
2 "	43.0	154.3	74.1	125.4	152.8	72.6	25.5	38.0	5.3	T
3 "	26.4	60.0	39.6	85.2	99.2	38.8	22.0	36.4	4.4	T
Sept. 5										
1 ft.	133.6	199.8	135.0	209.5	194.0	92.2	81.4	43.2	9.7	12.2
2 "	44.1	80.6	79.4	132.6	148.6	105.6	66.9	56.2	10.6	T
3 "	33.2	29.6	37.6	76.0	100.4	46.4	34.0	42.8	8.3	T
Sept. 13										
1 ft.	167.0	----	206.3	200.9	199.8	176.8	103.3	33.5	20.5	7.2
2 "	34.6	----	96.9	133.4	171.8	119.3	78.7	54.0	20.9	T
3 "	28.0	----	50.0	75.2	118.4	47.2	28.0	64.0	14.0	T
Sept. 22										
1 ft.	148.0	----	----	215.3	234.0	185.0	184.7	123.1	114.5	10.4
2 "	35.0	----	----	141.0	144.4	109.4	119.7	80.6	81.3	T
3 "	25.2	----	----	85.6	117.2	42.4	50.0	41.2	28.8	T
Sept. 26										
1 ft.	149.8	----	----	----	222.5	231.1	249.5	160.2	131.0	7.9
2 "	61.2	----	----	----	95.4	104.9	102.6	144.8	124.3	7.2
3 "	38.4	----	----	----	54.0	37.6	41.2	150.4	96.8	T
Oct. 10										
1 ft.	128.2	----	----	----	----	264.6	216.0	229.7	131.0	7.6
2 "	58.9	----	----	----	----	79.8	96.5	111.7	124.3	6.1
3 "	37.6	----	----	----	----	37.6	40.4	65.2	96.8	T

(continued)

Table XVII continued

Date planted & depth	Pounds of NO_3 per acre on date indicated									
	Aug. 27	Sept. 5	Sept. 13	Sept. 22	Sept. 26	Oct. 10	Oct. 24	Nov. 28	Mar. 3	May 19
Oct. 24										
1 ft.	128.5	----	----	----	----	----	209.5	229.7	262.8	74.5
2 "	58.1	----	----	----	----	----	85.1	111.7	119.7	124.6
3 "	39.6	----	----	----	----	----	38.4	65.2	27.2	49.6
Fallow										
1 ft.	----	----	----	----	----	----	----	247.7	254.5	216.4
2 "	----	----	----	----	----	----	----	101.1	80.6	140.2
3 "	----	----	----	----	----	----	----	37.6	26.8	52.8

T indicates trace

Table XVIII. Summary of soil nitrates (NO_3), 1931-1932.

Date planted	Pounds of NO_3 per acre, total for three feet, on date indicated: Sept. 14	Sept. 29	Oct. 6	Oct. 17	Oct. 24	Oct. 31	Apr. 15	Apr. 26	June 6
Aug. 29	675.9	630.9	537.6	506.5	629.8	586.4	199.5	----	57.1
Sept. 14	671.2	573.6	398.6	296.5	355.3	196.6	80.7	----	50.7
Sept. 29	622.5	565.4	422.0	375.6	512.9	309.8	68.7	----	46.5
Oct. 6	567.8	----	423.6	487.3	730.8	389.8	96.7	----	54.1
Oct. 17	472.5	----	----	507.4	664.7	462.6	112.9	54.3	46.2
Oct. 24	749.1	----	----	----	508.0	437.0	204.5	142.5	44.9
Oct. 31	552.8	----	----	----	----	448.4	141.7	81.0	55.5
Fallow	771.1	----	----	----	----	448.4	----	408.4	----

Table XIX. Summary of soil nitrates (NO_3), 1932-1933.

Date planted	Pounds of NO_3 per acre, total for three feet, on date indicated									
	Aug. 27	Sept. 5	Sept. 13	Sept. 22	Sept. 26	Oct. 10	Oct. 24	Nov. 28	Mar. 3	May 19
Aug. 27	272.4	400.8	264.9	391.0	445.0	173.7	88.5	123.7	17.3	10.0
Sept. 5	210.9	310.0	252.0	413.1	443.0	244.2	182.3	142.2	29.1	12.2
Sept. 13	229.6	----	353.2	409.5	490.0	343.3	210.0	156.5	55.4	7.2
Sept. 22	208.2	----	----	441.9	495.6	336.8	354.4	244.9	224.6	10.4
Sept. 26	249.4	----	----	----	371.9	373.6	393.3	453.4	352.1	15.1
Oct. 10	224.7	----	----	----	----	382.0	352.9	406.6	352.1	13.7
Oct. 24	226.2	----	----	----	----	----	333.0	406.6	409.7	248.7
Fallow	----	----	----	----	----	----	----	386.4	361.9	409.4

Wilson (10) in a study of factors affecting nitrification found that wheat unlike maize showed a depressing influence at the end of the first period (57 days after planting) and like maize continued to exert a depressing affect throughout its entire growth period.

A graphic presentation of the trend of NO_3 supply in the soil for each plot in 1932-1933 is given in Fig. 5 and data given in Table XIX. On August 27 when all plots were sampled, the amount of NO_3 varied from 208 to 272 pounds per acre. Precipitation of 5.6 inches in August and 4.17 inches in September maintained a supply of approximately 11 per cent of available moisture in all plots until the last of September. The mean temperature during August was 79.8 degress F. and during September 68.5 degrees F. A good supply of moisture and relatively high temperatures furnished ideal conditions for nitrification and the amount of NO_3 on all plots increased rapidly until September 26. There was relatively little precipitation during the latter part of September and during October. This resulted in some reduction of the amount of available NO_3 by October 10, and a drastic reduction by October 24 on the plots growing wheat. This reduction in moisture and a lower temperature evidently decreased nitrate formation. The graph shows a

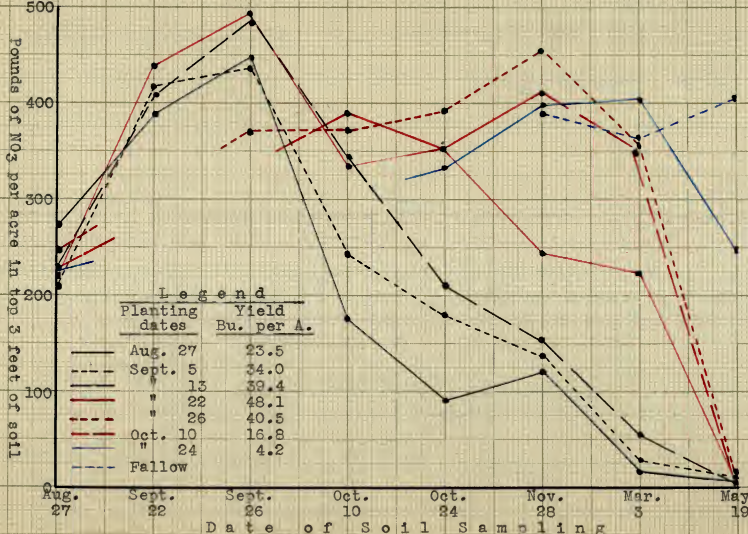

Fig. 5. Pounds of NO_3 at eight different samplings of wheat plots planted in 1932, on dates indicated.

reduction in the amount of NO_3, on the plots planted August 27, September 5, 13 and 22, by October 10 and a further reduction on the three earliest-planted plots by October 24. The amount of NO_3 on the plot planted September 22 is probably indicated as too low on October 10 or too high on October 24. This variation may be due to a variation in the soil at the point of sampling.

All plots, that had a sufficient number of culms on November 28 to produce a high yield of wheat, reduced the NO_3 to practically zero by May 19. The plot that made the highest yield, planted September 22, contained more NO_3 in the top three feet on November 28 and March 3, than any of the earlier-planted plots. The yield of all plots planted before the highest-yielding plot is in proportion to the amount of NO_3 in the plot on November 28 and March 3.

The relationship of soil nitrates, NO_3, and yield of wheat as influenced by date of seeding is summarized in Table XX and graphically illustrated for the 1932-1933 crop in Fig. 6.

The discussion of experimental work of this nature in the past has considered principally relation of yield and NO_3 in the soil at seeding time. Table XX and Fig. 6 show that there is a close relation between NO_3 at seeding time

Table XX. Relation of NO_3 in the soil on various dates to yield and percentage of protein in grain from wheat planted on seven dates in 1931 and 1932.

Date of seeding	Yield Bu. per A.	Protein in wheat %	Pounds of NO_3 per acre, in the first three feet: at seeding	Oct. 31	Apr. 15	June 6	Highest amt. at any time	Date of highest amount
			1 9 3 1 - 1 9 3 2					
Aug. 29	46.2	12.50	-----	586.4	199.5	57.1	675.9	Sept. 14
Sept. 14	52.1	11.10	671.2	196.6	80.7	50.7	671.2	Sept. 14
Sept. 29	60.1	11.35	565.4	309.8	68.7	46.5	622.5	Sept. 14
Oct. 6	65.2	12.45	423.6	389.8	96.7	54.1	730.8	Oct. 24
Oct. 17	61.4	13.30	507.4	462.6	112.9	46.2	664.7	Oct. 24
Oct. 24	45.6	13.95	508.0	437.0	204.5	44.9	749.1	Sept. 14
Oct. 31	36.1	14.30	448.0	448.4	141.7	55.5	552.8	Sept. 14
Fallow				448.4			771.1	Sept. 14
			1 9 3 2 - 1 9 3 3	Nov. 28	Mar. 3	May 19		
Aug. 27	23.5	14.30	272.4	123.7	17.3	10.0	445.0	Sept. 26
Sept. 5	34.0	14.65	310.0	142.2	29.1	12.2	443.0	Sept. 26
Sept. 13	39.4	14.65	353.2	156.5	55.4	7.2	490.0	Sept. 26
Sept. 22	48.1	16.00	441.9	244.9	224.1	10.4	495.0	Sept. 26
Sept. 26	40.5	15.90	371.9	455.4	352.1	15.1	455.0	Nov. 28
Oct. 10	16.8	18.00	382.0	406.6	352.1	13.7	406.0	Nov. 28
Oct. 24	4.2	19.25	333.0	406.6	409.7	248.7	406.0	Nov. 28
Fallow				386.4	361.9	409.4	409.4	May 19.

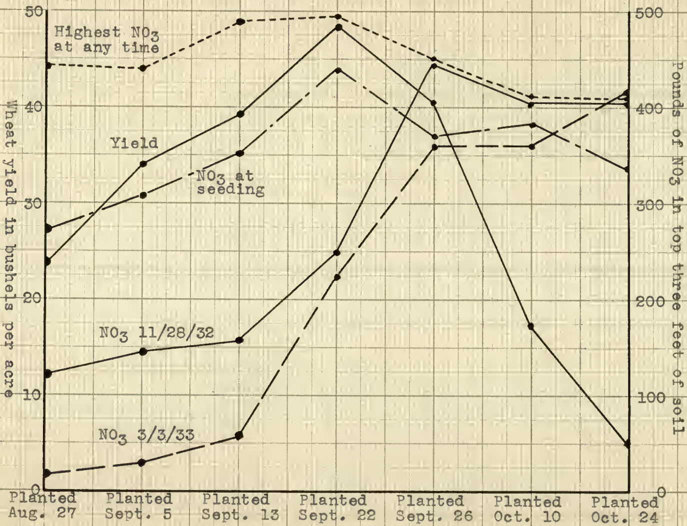

Fig. 6. Relation of pounds of NO_3 in the top three feet of soil to the yield of wheat planted in 1932, on dates indicated.

and yield on all plots planted before the one of highest yield, planted September 22, 1932. This relationship is not so close in the 1931-1932 plots, probably because the amount of NO_3 on all plots reached a very high point at seeding and was maintained throughout the year, as shown in Table XVIII. The amount of NO_3 in all plots on all dates even June 6, was high, and the supply of NO_3 was probably not a limiting factor affecting the 1932 yield. The reduction of yield in the early-planted plots is probably due to the thin stand on the August 29 plot and to Hessian fly on the September 14 plot. The lower yield on the October 24 and 31 plots is accounted for by the lack of stooling as indicated by the culm count given in Table V.

The low yield on the plots planted on October 10 and October 24, 1932, is apparently due to the lack of stooling as shown in both the November 28 count of stools and harvest culm count given in Table VI.

The amount of NO_3 was not so high in the 1932-1933 plots as in the 1931-1932 plots on corresponding dates. Practically all of the NO_3 was used by May 19, 1933. It is reasonable to expect, therefore, that on the 1932-1933 plots, NO_3 was a limiting factor.

Since the 1933 yield was in direct relation to the amount of NO_3 in the soil at seeding, it might be considered

that the amount of NO_3 at seeding was the controlling factor in yield. This relationship, however, may not be significant because of the fact, shown in Table XX and Fig. 6, that there was as much NO_3 in the soil at some time during the fall on all plots planted earlier than the plot of highest yield (September 22), as there was on that plot at planting time. The comparatively low amount of NO_3 in the earliest-planted plots at seeding was evidently due to the fact that NO_3 formation had been in progress a shorter time than on the later-planted plots. The amounts of NO_3 on the two earliest-planted plots were somewhat lower than on those planted September 13 and 22, due probably to the heavier demand for NO_3 by the larger plants on the early-planted plots.

There is a direct relation between the amount of NO_3 in the top three feet of soil, on both November 28 and March 3, and the yield of grain. This relationship is disturbed only when the wheat is planted later than the date of highest yield. This is probably due to a lack of stooling on the later dates. From these facts it would appear that it is necessary to secure sufficient fall growth to furnish enough culms per acre to use the available NO_3, but that more fall growth than this is detrimental when NO_3 is a limiting factor.

Relation of Weight of Dry Matter and Nitrogen in the Plant, Nov. 28, 1932, to Yield of Grain

Unpublished data recently secured by Dr. E. C. Miller, of Kansas State College, on the amount of nitrogen in the wheat plant at various stages, emphasize the necessity of a good supply of available NO_3 in the spring. Doctor Miller found that there was a very slow gain in the amount of nitrogen in the wheat plant until spring growth started. After the beginning of spring growth, the total amount of nitrogen in the plant practically doubled the first week and continued to increase rapidly until the middle of April, after which it slowed down materially. There was very little gain in total nitrogen in the plant after the first of May.

If the wheat plant absorbs the greatest part of its nitrogen in the spring, it is essential that there be a high amount of NO_3 in the soil at that time. The plots that were planted earlier than necessary which includes those planted August 27 and September 5 (Fig. 6), did not have the required amount of NO_3 in the soil when spring growth began and, therefore, could not proceed with the vegetative growth necessary to produce a high yield of grain.

The plant samples taken November 28, 1932, were dried, weighed and the nitrogen content was determined. These data presented in Table XXI and Fig. 7 show a negative relation of yield with both weight of plants and amount of nitrogen in the plants, from the earliest seeding, August 27, to the seeding of highest yield, September 22. This would indicate that nitrogen used in making a heavy growth in the fall was not all available for spring growth and future plant development. Observation of the plots in the spring support this supposition for much of the plant material on the early-planted plots was dried and dead while practically all of the plant material on the plots planted on a medium date was green. The early-planted plots had a larger number of stools on November 28 than they had culms at harvest, Table VI. This difference is evidently associated with a loss of plant material and a loss of available plant food. The plot of highest yield had more culms at harvest than stools on November 28. This increase was probably due to spring stooling and would indicate efficient use of both soil and plant nitrogen.

Gericke (6) in speaking of the use of nitrogen by the wheat plant says, "Some of the nitrogen required for vegetative production cannot be utilized later for protein in

the grain. A certain minimum amount becomes a part of the non-grain tissue. The more there is of this tissue, the less is the quantity of nitrogen available for grain."

Table XXI. Weight of dry matter and percentage of nitrogen in wheat plants when they entered dormancy, November 28, 1932.

Date of seeding	Yield Bu. per A.	Pounds of dry matter per acre	Nitrogen %	Pounds of nitrogen per acre
Aug. 27	23.5	3080.0	2.17435	67.7
Sept. 5	34.0	1847.5	2.7204	65.7
Sept. 13	39.4	1413.0	2.9686	54.8
Sept. 22	48.1	888.3	3.2069	28.5
Sept. 26	40.5	540.7	3.2863	17.8
Oct. 10	16.8	145.2	3.3062	4.8
Oct. 24	4.2	0.0	0.0	0.0

Relation of Protein Content of Grain to Nitrate Supply as Influenced by Date of Seeding

Two important factors of quality in wheat that may be influenced by date of seeding are protein content and weight per bushel. A high protein wheat is usually in demand by millers. Wheat that has a higher protein content than is required for flour manufacture is of value in blending with wheat of low protein to bring the mixture to the required standard. A high test weight is important because there is a positive correlation between weight per

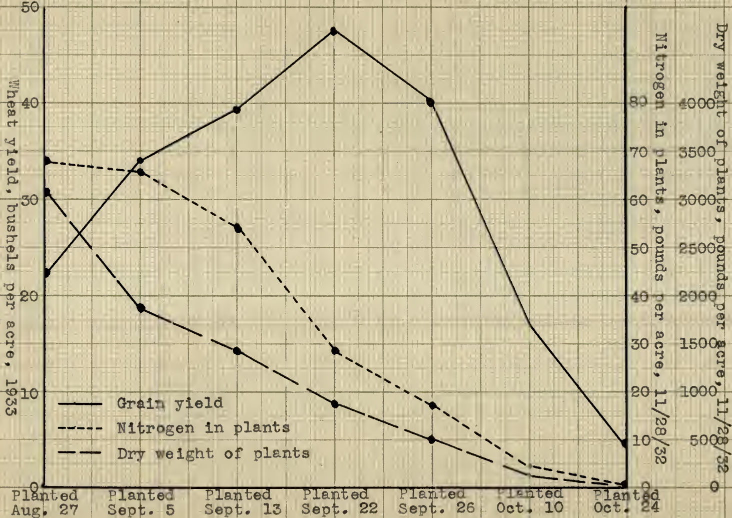

Fig. 7. Relation of weight of dry matter and nitrogen in plants on Nov. 28, 1932 to yield of wheat planted on dates indicated.

bushel and percentage of flour among samples of the same variety.

In general, the percentage of protein in the grain harvested from the 1931-1932 plots increased with the lateness of planting. The plot planted August 29 was an exception in that the protein content of this grain was higher than that from the plots planted on the next three dates, as shown in Table XXII.

Table XXII. Yield and quality of grain from wheat planted on different dates.

Date of seeding	Yield Bu. per A.	Protein in wheat %	Protein in wheat Lbs. per A.	Weight per bu. of grain	Date of ripening
		1931 - 1932			
Aug. 29	46.2	12.50	346.5	59.9	
Sept. 14	52.1	11.10	346.65	59.9	
Sept. 29	60.1	11.35	409.74	60.5	
Oct. 6	65.2	12.45	487.17	60.8	
Oct. 17	61.4	13.30	490.12	61.4	
Oct. 24	45.6	13.95	381.49	58.6	
Oct. 31	36.1	14.30	309.88	56.6	
		1932 - 1933			
Aug. 27	23.5	14.30	201.63	55.3	June 15
Sept. 5	34.0	14.65	284.13	56.6	" 16
Sept. 13	39.4	14.65	346.32	56.8	" 17
Sept. 22	48.1	16.00	461.76	56.6	" 17
Sept. 26	40.5	15.90	386.37	56.3	" 17
Oct. 10	16.8	18.00	181.44	46.3	" 20
Oct. 24	4.2	19.25	48.57	41.0	" 21

The percentage of protein in the wheat harvested from the 1931-1932 plots is not related to the amount of NO_3 in

the soil at seeding nor on April 15 as given in Table XX. There is, however, relationship between the percentage of protein and the NO_3 in the soil on October 31. The NO_3 content of all soil samples taken from the 1931-1932 plots was so high that NO_3 was probably not a limiting factor at any time during the growth of the crop. Therefore, a relationship between percentage of protein and supply of NO_3 would not be expected.

The data from the 1932-1933 plots show a positive correlation between the amount and percentage of protein in the wheat harvested from the plots planted on and before the date of highest yield and the NO_3 in the soil on both November 28, 1932, and March 3, 1933. This relationship is shown graphically in Fig. 8.

The increase of the percentage of protein in the grain from the plots planted later than the plot of highest yield may have been due to two factors; a greater amount of NO_3 in the soil, and the failure of this grain to finish filling. The October 10 and October 24 plots ripened from three to four days later than the other plots. The high temperature of June and the shortage of moisture stopped the development of the grain prematurely. This is evidenced by the shriveled condition of the grain as indicated by the low test weight given in Table XXII.

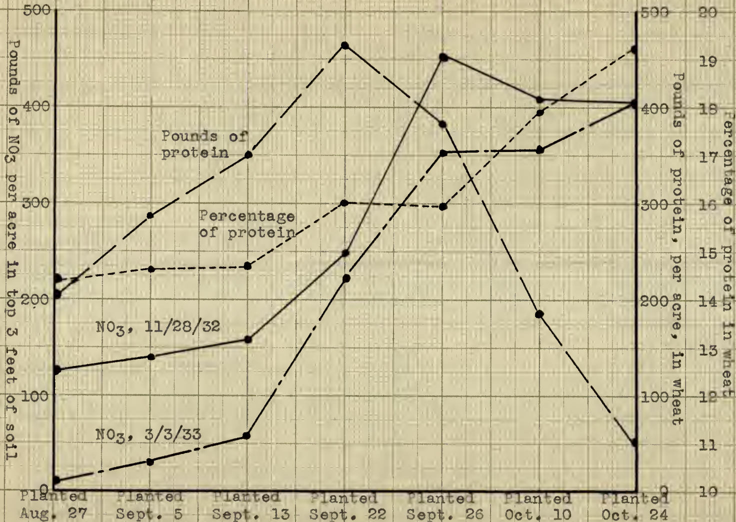

Fig. 8. Relation of pounds of NO_3 in the top three feet of soil, percentage of protein, and pounds of protein per acre in wheat planted in 1932, on dates indicated.

Relation of Weight per Bushel to Nitrate Supply

There is some relationship indicated between the supply of NO_3 and the weight per bushel of grain except when the wheat was planted late. Late-planted wheat usually ripens late and often produces grain of low test weight due to the shriveling effect of hot, dry weather at that time. Data given in Table XXII show that the test weight of wheat grown on plots planted later than October 17, 1931, and September 26, 1932, decreased in weight per bushel. This agrees with data secured from the date-of-seeding plots conducted by the Kansas Agricultural Experiment Station from 1920 to 1930.

There is no definite relationship between NO_3 supply in the soil and test weight of grain from plots planted before the date of highest test weight, October 17, 1931. This may be accounted for by the fact that Hessian fly reduced the growth of the wheat on the three earliest-planted plots and that the NO_3 supply was so high on those plots that it is doubtful if it was a factor at any time.

On the 1932-1933 plots, a definite relationship is indicated between the NO_3 content of the soil as given in Table XX and the test weight of the grain as given in Table XXII.

The NO_3 supply in the soil at seeding increased as the plots were planted later until after September 22. It is doubtful, however, if this was a factor since, as previously stated, the amount of NO_3 on all plots was as high or higher by September 26 than on the September 13 plot at planting time. The weight of grain per bushel on the plots planted August 27, September 5 and September 13 increased from the earliest to the latest-planted plot. The amount of NO_3 in the soil on these plots on November 28 and March 3, increased in the same direction as the weight per bushel. Thus wheat of high test weight was produced where there was an ample supply of NO_3 during the growing season.

SUMMARY AND CONCLUSIONS

This experiment was undertaken to study the relation of the date of planting wheat to the yield and quality of grain produced, the supply of available NO_3 in the soil at various stages of plant growth, the supply of available moisture, and the stand and stooling of the plants.

Duplicate plots were planted on seven dates in the fall of 1931 and in 1932. Soil and plant samples were taken from the first of each pair of plots and the second was harvested for grain yields. Soil samples of the first,

second and third foot levels were taken at various times from the date of planting the first plot until harvest. Determinations of moisture and NO_3 in the soil provided data for the study of their utilization by the plant.

Hessian fly was a factor influencing the yield of the early-planted plots in 1932 when Kanred, a susceptible variety, was planted, but the fly was not a factor in 1933 when Kawvale, a resistant variety, was seeded.

Climatic conditions were such as to produce a fairly high yield each year. High temperatures and drouth in June, 1933, reduced yields on all plots that year.

A positive correlation was found between yield and number of culms at harvest time. The ratio of culms to yield was relatively higher in the early plantings than at the intermediate and later dates. Both number of culms and yield decreased rapidly in wheat seeded after September 22 in 1932. The smaller number of culms was apparently the cause of the reduction in yield.

Since there was available moisture in the soil on all plots at each sampling in 1932 and since the available moisture on the highest-yielding plot, which was planted September 22, was lower on May 19, 1933, than that on any other plot, it is concluded that moisture in 1933 did not

affect the yield or protein content of the grain from plots planted before or after the highest-yielding plot more than it did this plot.

The yields for both 1932 and 1933 were noticeably lower on the early and on the late-seeded plots than on those seeded on intermediate dates. This agrees with results obtained by the Kansas Agricultural Experiment Station over a period of eleven years.

A close correlation between yield and pounds of NO_3 per acre at seeding time was shown in 1932 for all plots planted on or before September 26. This relation may not be due to a shortage of nitrogen in the fall since the NO_3 per acre on the early-planted plots was as high at some time during the fall as it was on the highest-yielding plot at seeding time, which was September 22.

The later the wheat was sown, the greater was the amount of NO_3 in the soil when the wheat went into dormancy (November 28) and when it emerged in the spring (March 3). Some variation from this relationship was found in the November 28 curve on the two latest-planted plots. This variation is slight and probably did not influence the yield.

The higher the amount of NO_3 in the soil on November 28, 1932, and March 3, 1933, the higher was the yield of

wheat with the exception of those plots planted after the date of highest yield. The relatively low yields of the later-planted plots may have been caused by an inadequate number of heads to make efficient use of the NO_3 and moisture available or by late maturity due to lack of fall growth.

The pounds of nitrogen per acre in the plants on November 28, 1932, decreased while the percentage of nitrogen increased from the earliest-sown plots to the latest-sown plots. There is a negative correlation between the amount of nitrogen per acre in the plants on November 28 and the yield of wheat on those plots sown from August 27 to and including the plot of highest yield, which was sown September 22. This relationship also exists between weight of plants on November 28 and yield.

The pounds of protein per acre in the grain increased from the earliest date of planting to the September 22 planting and decreased in later plantings. The pounds of protein produced per acre correlated with the yield and with the November 28 and March 3 nitrates from the earliest planting to that of highest yield, September 22. The percentage of protein in the wheat increased from the earliest sowing to the latest sowing and has the same general trend as the NO_3 on November 28 and March 3.

The weight per bushel of grain was associated directly with yield and with the supply of NO_3 in the soil during the spring growing period of the plant.

The results of this study indicate that early-sown wheat grown under conditions of adequate but not excessive moisture and a limited amount of NO_3 in the soil, probably will not make as high yields nor produce wheat of as high protein content as wheat sown somewhat later. This may be explained in part at least by the fact that the early-sown wheat uses a large amount of NO_3 for fall growth and thus reduces the supply available for spring growth. Much of the nitrogen used in fall growth is not available for grain formation.

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